

Acoustic Characterization of Mesoscale Objects

Mesosience is an emerging area of science and engineering that focuses on the study of materials with dimensions, features, and structures that range from a few millimeters down to a few micrometers. Mesoscale nondestructive characterization technologies are required that can 1) penetrate into or through a few millimeters of diverse materials, and

2) provide spatial resolution of about a micrometer.

In addition to the spatial resolution requirements, many mesoscale objects require a noncontact technique to avoid damaging fragile surfaces. An acoustic technique is attractive because it offers high sensitivity to features such as thickness and interface quality that are important to mesoscale objects.

Project Goals

This research will achieve micrometer resolution characterization by extending the range of laser-acoustic testing (Fig. 1) to GHz frequencies. Materials and the geometry of components used in most LLNL mesoscale objects necessitate the use of a noncontact technique at frequencies from 100 MHz to 10 GHz. This frequency range is required to acoustically characterize features from 5 to 0.5 μm in size. For LLNL applications, mesoscale structures are on the order of 25 to 200 μm thick.

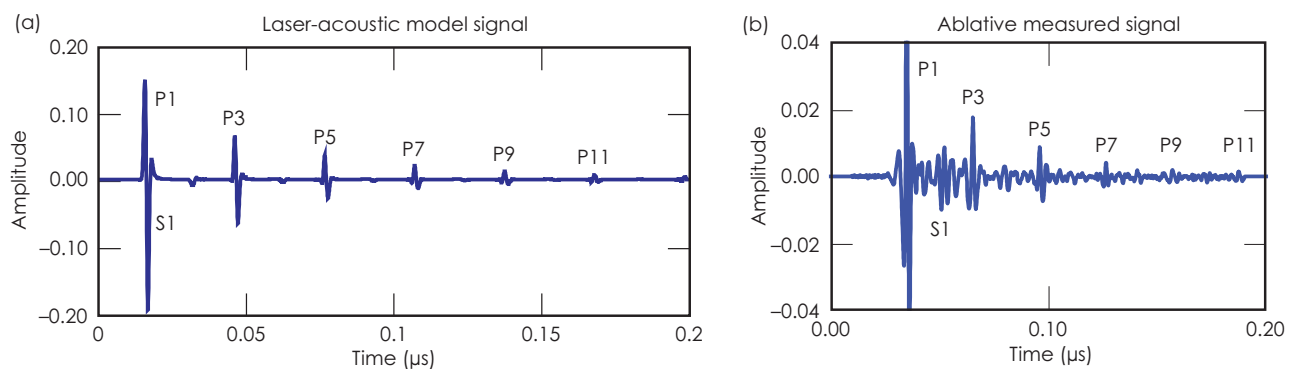
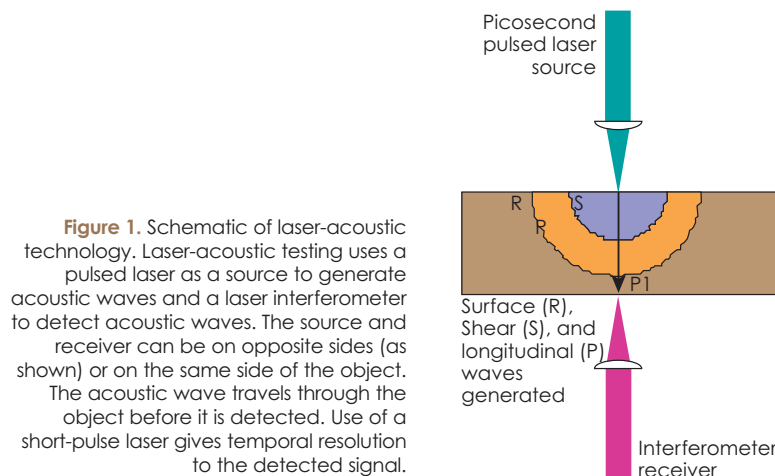


Figure 2. Results from experiments using the configuration in Fig. 1. Temporal signals from (a) modeled and (b) measured signals for a 100- μm -thick aluminum film show good correlation. Each peak in the signal represents an arrival of an acoustic wave at the epicentral location. The model in (a) combines a 2-D analytical laser-interaction solution with the LLNL E3D finite-difference acoustic wave propagation code. The modeled signal shows only longitudinal components (P) and does not capture shear (S) modes adequately. The measured signal in (b) shows higher shear components (S1) and has measurement noise.



For more information contact
Diane Chinn
 (925) 423-5134
chinn3@llnl.gov

Relevance to LLNL Mission

This work directly addresses metrology and characterization gaps of interest for LLNL's mesoscale manufacturing R&D. As a characterization technique, the work also contributes to our Sensors-to-Knowledge toolbox. Of the different mesoscale characterization challenges at LLNL, the most relevant are the targets prepared for OMEGA and NIF. This proposal impacts the DNT, NIF, Engineering, and Chemistry and Materials Science Directorates through laser target fabrication and characterization.

FY2005 Accomplishments and Results

Major accomplishments to date are:

1. the determination of ultrasonic

velocity and attenuation in several materials important to LLNL, at frequencies ranging from 500 MHz to 1 GHz, for thermoelastic and ablative wave generation;

2. the validation of acoustic and laser-acoustic models with experimental data (Fig. 2); and
3. the assembly of a prototype GHz laser ultrasound (UT) system (Fig. 3). The prototype system was assembled at Boston University and was transferred to LLNL in FY2005. This work is described in Reference 3.

Related References

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3. Huber, R. H., D. J. Chinn, O. O. Balogun, and T. W. Murray, "High Frequency Laser-Based Ultrasound," *Review of Progress in Quantitative Nondestructive Evaluation*, August 2005.
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5. Scruby, C., *Laser Ultrasonics: Techniques and Applications*, Adam Hilger, New York, 1990.

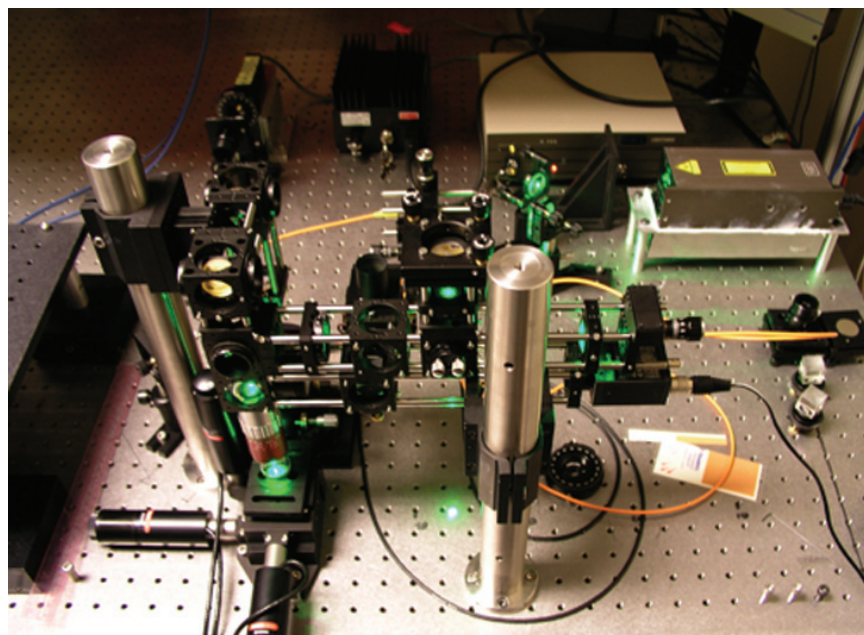


Figure 3. The tabletop GHz laser-acoustic system uses a picosecond Nd:Yag laser to generate the acoustic wave and a frequency-doubled Nd:Yag laser in continuous-wave mode for interferometric detection of the acoustic wave. The source laser has a 4- μ m spot, a 1.1-ns pulse length, and operates at approximately 0.15 mJ in ablative mode. The detection laser has a 600-nm spot.

FY2006 Proposed Work

Our work to date has enabled new research on acoustic wave generation, scattering mechanisms, and interface characterization in the GHz regime. Research in FY2006 will cover these specific areas:

1. Identifying the thermoelastic-ablative threshold for materials through modeling is important to applications requiring "sub-ablative" wave generation. GHz laser-acoustic wave generation will be studied with advanced laser-interaction models.
2. Interfaces such as repeating structures and gaps sized on the order of micrometers are two areas where performance of GHz waves is unknown. Capabilities of GHz characterization of interfaces will be studied using models and experiment.